

Astronomy (SOFIA) Program; the SOFIA Program wanted the engines as spares, so the SCAs “probably won’t fly anymore.”⁴⁸

Function:

The SCAs primary function was to ferry the Space Shuttle orbiters from one location to another. The SCAs delivered the newly assembled orbiters to KSC to begin their operational service. NASA 905 delivered four of the five orbiters, *Columbia* (March 1979), *Challenger* (July 1982), *Discovery* (November 1983), and *Atlantis* (April 1985); NASA 911 delivered *Endeavour* (May 1991). Between April 1981 (STS-1) and July 2011 (STS-135), the SCAs completed fifty-five post-mission ferry flights following an orbiter’s landing at Edwards AFB or White Sands Space Harbor. In addition to the post-mission flights and initial deliveries, between 1985 and 2001, the SCAs transported the orbiters between KSC and Palmdale, for eight modification periods (sixteen one-way ferry flights).

Flight Procedures

In order to carry the orbiter from one place to another, the vehicle had to be attached to the SCA. This task was completed using one of two MDD structures (one at DFRC and one at KSC), an Orbiter Lifting Frame (at Palmdale), or, if necessary, stiff-legged derricks. First, a tail cone to reduce aerodynamic drag was attached to the orbiter’s base heat shield at eight attach points; this took two to three shifts to accomplish. After the orbiter was raised about fifty feet, the SCA was towed underneath, and the orbiter was lowered into position and attached at the two aft and one forward points. These three attach locations were the same as those used when the orbiter was mated to the ET. The mate process typically took about twelve hours.⁴⁹

The SCA was required to fly only during daylight hours. Chief Flight Engineer, Henry Taylor, noted that the SCA was allowed to take off up to twenty minutes before sunrise, and had to land no later than twenty minutes after sunset. The flight path was determined mostly by the weather, and generally was not the same for each ferry operation. The

⁴⁸ Taylor, interview, 16-17. SOFIA uses a highly modified Boeing 747SP aircraft as a platform for the 100”-diameter, 19-ton reflecting telescope, which is mounted in the rear fuselage. SOFIA is the world’s largest airborne astronomical observatory. Pearlman, “NASA Space Shuttle.”

⁴⁹ McCormack, interview, 2-4. For post-mission ferry flights, the orbiter typically was ready to be ferried within seven to nine days of landing. For additional information on the KSC MDD, see Patricia Slovinac, “Cape Canaveral Air Force Station, Launch Complex 39, Shuttle Landing Facility (John F. Kennedy Space Center),” HAER No. FL-8-11-J. Historic American Engineering Record (HAER), National Park Service, US Department of the Interior, April 2011.

orbiter could not be flown through rain, to prevent damage to the tiles. Severe weather also was avoided. Temperature and pressure were additional constraints; the minimum temperature was 15 degrees Fahrenheit (F) and the minimum ambient pressure was 8 psia (pounds per square inch absolute). Because of these limits, the SCA generally flew low, in the range of 11,000' to 16,000'.⁵⁰ Before every flight leg, a weather briefing was conducted to determine if the flight could proceed.

The weight of the orbiter impacted the performance of the SCA; the mated SCA/orbiter could weigh no more than 710,000 pounds at takeoff.⁵¹ The typical weight range for end-of-mission ferry flights was about 195,000 to 230,000 pounds.⁵² When the orbiters were initially delivered to KSC, their estimated weights ranged from 158,289 pounds (*Columbia*) to 151,205 pounds (*Endeavour*), without the engines installed.⁵³ Following the eight major modifications performed at Palmdale, orbiter weight ranged between approximately 154,000 and 161,000 pounds. The heaviest orbiter ever ferried was *Discovery* after STS-114; it carried a multi-purpose logistics module in the payload bay, and weighed almost 228,000 pounds. To help balance the SCA for ferry flights, 7,000 pounds of pea gravel were added; the pea gravel was contained in cargo containers in the lower forward cargo bay.⁵⁴

The aircraft crew for ferry flights consisted of two pilots and one or two flight engineers.⁵⁵ During the transcontinental trip between California and Florida, the SCA typically stopped several times to refuel. A heavier orbiter required at least three refueling stops, sometimes four. A refuel required only a few hours on the ground. The average fuel burn for the SCA during a ferry flight was about 5,750 gallons per hour.⁵⁶ Historically, more than twenty military bases and a few international airports located across the southern one-third of the US supported ferry operations. Military bases were used almost all the time because of their security and

⁵⁰ McCormack, interview, 6.

⁵¹ Taylor, interview, 7.

⁵² Variable orbiter weight resulted, foremost, from what was returned in the payload bay. McCormack, interview, 8.

⁵³ The SSMEs added approximately 20,000 pounds to the total empty weight of each orbiter. NASA KSC, "Orbiter Vehicles," <http://www.pao.ksc.nasa.gov/shuttle/resources/orbiters.html>.

⁵⁴ Gray Creech, "Gravel Haulers: NASA's 747 Shuttle Carriers," August 22, 2003, http://www.nasa.gov/news/special/747_Shuttle_Carriers_prt.htm.; Pete Seidl, interview by Joan Deming and Patricia Slovinac, September 18, 2006; Arvid C. Knutson, interview by Jennifer Ross-Nazzal, *Shuttle Carrier Aircraft Oral History Project*, April 13, 2012, 2.

⁵⁵ Typically, two flight engineers were required for a post-mission ferry flight; only one was needed for all other ferry flights. McCormack, interview, 6.

⁵⁶ McCormack, interview, 10, 12.

support capabilities.⁵⁷ Generally, Air Force bases were favored because they have long runways.⁵⁸

Under the most favorable conditions, with good weather and a light orbiter, the cross-country trip could be made in one day with two legs; with bad weather, it could stretch out to four days or more. Typically, a ferry flight was accomplished in three or four legs flown over a period of two to three days, with one or two rest stops. Ferry flights averaged three legs per flight; all but four ferry flights were made in two to four legs. *Columbia*, *Discovery*, and *Atlantis* each had a single five-leg ferry flight following missions STS-35, STS-42, and STS-76, respectively. The initial delivery of *Endeavour* entailed a six-leg journey.

A “pathfinder” aircraft, flown by an experienced SCA pilot, took off prior to the SCA and flew approximately 100 miles ahead. The type of aircraft used as the pathfinder varied. In the winter, there were requirements to provide a heated purge of the orbiter at overnight stopovers if the overnight temperature was expected to be below 45 degrees F for more than four hours. Therefore, specialized purge equipment was needed. In these cases, a USAF C-141 or C-17 was used as the pathfinder aircraft. When purge equipment was not needed, a NASA JSC aircraft, such as a KC-135 or a C-9, typically served as the pathfinder vehicle. The pilot in the pathfinder was in radio contact with the pilots in the SCA, providing guidance to safely navigate through challenging weather conditions.⁵⁹ The pathfinder also transported all required support equipment and the thirty to thirty-five person ferry flight team, including the ferry manager, weather officers, all the KSC support personnel, the mechanics and maintenance crew, and safety and security personnel.⁶⁰

Upon landing at a stopover, a safety assessment was performed before the flight crew could depart the SCA. This consisted of toxic vapor tests and visual inspections for damage performed by KSC personnel. In the case of an overnight stop, base security personnel set up a perimeter that was at least 200’ from the SCA. Military personnel controlled the single entry point established and monitored the restricted area.⁶¹ When the plane landed at its final destination, a safety assessment was conducted, and then

⁵⁷ Taylor, interview, 21.

⁵⁸ Larry LaRose, interview by Jennifer Ross-Nazzal, *Shuttle Carrier Aircraft Oral History Project*, April 12, 2012, 5.

⁵⁹ McCormack, interview, 8-9.

⁶⁰ Taylor, interview, 22.

⁶¹ McCormack, interview, 12.

the mated vehicle was towed to the MDD. Typically, within about sixteen hours, the orbiter was demated from the SCA.⁶²

⁶² McCormack, interview, 15.